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REVIEW OF CURRENT PHYSICAL SECURITY MODEL CAPABILITIES

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This report reviews literature pertaining to physical security and related simulation models, to determine the human factors attributes and human performance capabilities that have been included. It concluded that few attempts have been made to include a significant level of human factors attributes or human performance models in existing security system evaluations.

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CONTENTS

Section		Page
1	INTRODUCTION	3
2	CURRENT PHYSICAL SECURITY MODEL CAPABILITIES	4
	2.1 MODEL-INSIDER SAFEGUARDS EFFECTIVENSS MODEL (ISEM)	5
	2.2 MODEL-FORCIBLE ENTRY SAFEGUARDS EFFECTIVENESS MODEL (FESEM)	7
	2.3 MODEL-SAFEGUARDS NETWORK ANALYSIS PROCEDURE (SNAP)	9
	2.4 MODEL-MATRIX ANALYSIS OF THE INSIDER THREAT (MAIT)	10
	2.5 MODEL-TECHNICAL SUPPORT ORGANIZATION PHYSICAL PROTECTION SIMULATION (TSO)	11
	2.6 MODEL-TRW PHYSICAL SECURITY DESIGN AND EVALUATION METHODOLOGY	13
	2.7 MODEL-FIXED SITE NEUTRALIZATION MODEL (FSNM)	15
	2.8 MODEL-PHYSICAL SECURITY SYSTEM PERFORMANCE ANALYSIS METHODOLOGY (SSPAM)	16
	2.9 MODEL-EASI	18
	2.10 MODEL-VISA	19
	2.11 MODEL-ADVERSARY ACTION MODELING	20
	2.12 MODEL-SDC TRANSPORTATION MODEL	21
3	ARMED FORCES INTERACTION MODELS	22
	3.1 MODEL: ARMED ESCORT MODEL	23
	3.2 MODEL: AIRCAV	24
	3.3 MODEL: AMSWAG	25
	3.4 MODEL: CARMONETTE	26
	3.5 MODEL: DYNTACS	27
	3.6 MODEL: JOLIWACO	28
	3.7 MDOEL: SIAF	29
	3.8 MODEL: TAM	30
4	SMALL GROUP ENGAGEMENT MODELS	31

CONTENTS (Continued)

Section		Page
	4.1 MODEL: SABRES	33
	4.2 MODEL: SCHAFFER'S AMBUSH MODEL	34
	4.3 MODEL: SOURCE	35
	4.4 MODEL: TSEM	36
	4.5 MODEL: ANALYTIC ENGAGEMENT MODEL	37
	4.6 MODEL: BONDER/IUA	38
	4.7 MODEL: BREAKPOINTS IN LAND COMBAT	39
	4.8 MODEL: COUNTERMEASURES ENGAGEMENT ANALYSIS	40
	4.9 MODEL: DAYLIGHT ASSAULT MODEL	41
	4.10 MODEL: FIREFIGHT	42
	4.11 MODEL: GCC FIREFIGHT	43
	4.12 MODEL: ICM	44
	4.13 MODEL: INTERDICTION MODEL	45
	4.14 MODEL: MARKOV ENGAGEMENT MODEL	46
	4.15 MODEL: MATH MODEL OF INFANTRY COMBAT	47
	4.16 MODEL: PRENETRATION ATTRITION MODEL	48
5	REFERENCES	49

SECTION 1
INTRODUCTION

This report is submitted in satisfaction of technical requirement 5.1.1 of Contract N00123-79-C-1446. As described in Technical Requirement 5.1.1 of the subject contract the available documentation on the most applicable current physical security models has been reviewed. The results of this review are presented in Section 2.0 of this report. The absence of behavioral models in the current physical security models led us to expand the scope of the literature review to include selected small unit Armed Force interaction models, which are presented in Section 3.0 and small unit engagement models, which are presented in Section 4.0 of this report.

SECTION 2
CURRENT PHYSICAL SECURITY MODEL CAPABILITIES

This section presents the results of a review of twelve models developed specifically for evaluation of physical security systems. All of these models describe land based sites and most of them are designed to evaluate physical security safeguards for Special Nuclear Materials (SNM) at nuclear materials processing plants. Two exceptions to this rule are the TRW Physical Security Model, which has been used to evaluate building security and the Mission Research Corporation (MRC) Security System Performance Analysis Methodology (SSPAM), which is being developed to evaluate physical security of Service operated nuclear weapons storage sites.

These models, developed specifically to address physical security, were considered to be the models most applicable to the modeling of shipboard security. Because this research program addresses human behavior as it relates to shipboard security, these models were reviewed primarily from the standpoint of the human attributes and human performance functions that were included in the models. With two exceptions, it was found that very few human (behavioral) attributes and essentially no behavior-related models have been included in current physical security models. The exceptions are the Vector Research Incorporated Fixed Site Neutralization Model (FSNM) and the MRC SSPAM.

2.1 MODEL-INSIDER SAFEGUARDS EFFECTIVENESS MODEL (ISEM)[1]

DEVELOPER - Sandia Laboratories

LANGUAGE - GASP IV

PERSONS INCLUDED - Employees, guards

PERSONNEL ATTRIBUTES -

Employees: authorized access to areas
explosives on person
SNM on person

Guards: authorized access to areas
authorized access to portals

PERSONNEL FUNCTIONS -

Employees: motion
disable sensor
disable sensor communications
engagement

Guards: motion
engagement

ENGAGEMENT - Discrete state, continuous time stochastic process

DISCUSSION - The facility is described in terms of areas, barriers and portals. Motion is modeled in terms of the time interval required to cross an area or pass through a portal. The time intervals are obtained by a draw from a triangular probability density function, where the mean and standard deviation crossing or passage time are specified for each area and portal, respectively. Insider tampering with a sensor or alarm communications is modeled as a user specified time delay and probability of success. Engagements occur at user specified locations following an alarm if a guard and insider arrive at the same area or portal at the same time.

The engagement model describes the engagement states in terms of adversary force size, guard force size and arriving guards. State transitions are obtained by sampling probability density functions dependent upon current force sizes, force weapons level (low, medium, high) and force competence level (low, medium, high). ISEM contains only the attribute of combat competence level and no human performance models.

2.2 MODEL - FORCIBLE ENTRY SAFEGUARDS EFFECTIVENESS MODEL (FESEM)[2]

DEVELOPER - Sandia Laboratories

LANGUAGE - GASP IV

PERSONS INCLUDED - Guards, adversaries

PERSONNEL ATTRIBUTES -

Adversaries: number
weapon type
barrier penetration resources
mobility
dedication/sophistication

Guards: number of on-site response forces
number of off-site response forces
communications probability
dedication/sophistication
response time

PERSONNEL FUNCTIONS -

Adversaries: motion
barrier penetration
tampering (sensor or sensor communications)
engagement

Guards: motion
engagement

ENGAGEMENT - Tenth order nonlinear Lanchester equation with time varying coefficients

DISCUSSION - FESEM is a computer model for analyzing the effectiveness of fixed-site nuclear safeguards against a forcible attack by an adversary intent on sabotage or theft. The model applies Monte Carlo methods to problems of forcible entry for any assumed path by an adversary with specified characteristics and estimates the probable adversary success. The evaluation technique includes variables related to detection assessment, communication, delay and neutralization. The physical security system is

modeled as a system of concentric shells of barriers and alarms with response forces. All guard and adversary motion is along radial lines. Motion, barrier penetration and tampering are modeled as delay times drawn from triangular probability density functions. Tampering also includes a user specified probability of success.

The engagement model allows ambushes, which are transformed to engagements as the ambushees "take cover" and start to return fire. During the transition from ambush to engagement the ambushee's firepower effectiveness is allowed to increase.

The only human factors attribute included in FESEM is the dedication/ sophistication parameter. This attribute is specified as high, medium or low, and is used principally in the engagement model to affect engagement proficiency and surrender or quit criteria. No human performance models are included in FESEM.

2.3 MODEL - SAFEGUARDS NETWORK ANALYSIS PROCEDURE (SNAP)[3]

DEVELOPER - Pritsker and Associates (for Sandia Laboratories)

LANGUAGE - GASP IV

PERSONS INCLUDED - Adversaries, guards

PERSONNEL ATTRIBUTES -

- Adversaries:
  - number
  - weapons
- Guards:
  - number
  - weapons
  - training level

PERSONNEL FUNCTIONS -

- Adversaries:
  - motion
  - disable a barrier or sensor
  - engagement
- Guards:
  - motion
  - engagement

ENGAGEMENT - Uses the Sandia Laboratories BATL engagement model

DISCUSSION - The facility is described in terms of areas, barriers and portals that are adjacent to one another. The security system is described in terms of guards, sensors and alarms. Conditions for and probabilities of detection and alarm are user specified. Detection and engagement can occur under user specified conditions if a guard and an adversary arrive simultaneously at the same block. Motion is defined by the time required to cross a block and is obtained by a draw from a probability density function, with user specified mean and standard deviation for each block. Disabling a barrier or sensor is characterized by a required time drawn from a probability density function and a user specified probability of success.

Engagements are simulated by the BATL model which requires as inputs force sizes, weapon type and, for guards, training level.

2.4 MODEL - MATRIX ANALYSIS OF THE INSIDER THREAT (MAIT)[4]

DEVELOPER	- Science Applications Incorporated (for Nuclear Regulatory Commission)
LANGUAGE	- GASP IV
PERSONS INCLUDED	- Employees, guards
PERSONNEL ATTRIBUTES	- Identification Authorized access Authorized control
PERSONNEL FUNCTIONS	- Movement Access Control
ENGAGEMENT	- None

DISCUSSION - The design of MAIT does not allow inclusion or consideration of human factors or performance. MAIT is concerned with all of the possible paths from one point to another, together with the safeguards along that path. The insider is assigned certain access and control priviliges associated with his job, and it is assumed that whatever he can do he will do to achieve his goal.

2.5 MODEL - TECHNICAL SUPPORT ORGANIZATION PHYSICAL PROTECTION SIMULATION (TSO)[5,6]

DEVELOPER - Brookhaven National Laboratories

LANGUAGE - FORTRAN (?)

PERSONS INCLUDED - Defenders, attackers

PERSONNEL ATTRIBUTES -

Defenders: number
location
time to alert
transport mode and rate of movement
adversary detection range

Attackers: number
location
barrier penetration resources
transport mode and rate of motion
delay in assessing progress of attack

PERSONNEL FUNCTIONS -

Defenders: movement
detection

Attackers: movement

ENGAGEMENT - Engagement is modeled as a delay only, with no attrition.

DISCUSSION - The facility is modeled as a series of concentric circles, with straight line motion along radial lines. Barrier penetrations are modeled as delays, alert and assessment delays are user specified. Detection is automatic when the defender-adversary range is less than the adversary detection range. An engagement is modeled as a delay of length proportional to the ratio of defenders to attackers. The model computes the outcome of an invariant input adversary action sequence. The result is deterministic, all variables and parameters are fixed for a given case,

and uncertainties are not included. Detection is assumed to occur at one of three user specified locations: at the perimeter, at an inner barrier, or at specified locations between the perimeter and inner barrier. All three cases may be evaluated. The evaluation model is divided into two phases: the access phase, which ends when the intruders gain access to the SNM, and the removal phase which involves travel of the intruders and guards to an interception point. The modeling of sensors and guards is unrealistic in many ways. For example, the treatment of sensors neglects their probabilistic behavior, and the treatment of guards neglects their human attributes. The modeling of guard positions and movements oversimplifies the geometric realitites involved.

2.6 MODEL - TRW PHYSICAL SECURITY DESIGN AND EVALUATION METHODOLOGY[7,8]

DEVELOPER - TRW Systems Group

LANGUAGE - Unknown (probably GASP IV)

PERSONS INCLUDED - Adversaries, guards, insiders

PERSONNEL ATTRIBUTES -

Adversary/insider: capability to defeat barriers, alarms, locks
attack type (overt/covert)
recognizability

Guards: force posture
procedures per post

PERSONNEL FUNCTIONS - Movement
performance of specified tasks

ENGAGEMENT - No engagement is modeled

DISCUSSION - All possible paths from an initial assault point to the intended target are identified and the model uses graph techniques to evaluate the progress of the attack from grid point to grid point. The attack may employ outsiders or insiders using either stealth or force. If stealth is used the measure of security system effectiveness is the cumulative probability of adversary detection. If force is used the measure of system success is the delay time imposed on the attackers by the system. Adversary and guard attributes are translated into delay times, probabilities of success in performing specified tasks and probabilities of detection. Visible and aural detection are modeled.

The facility is characterized in terms of walls, doors, locks, and other familiar items. Detection is provided by sensors and roving guard patrols. The sensors modeled include ultrasonic, closed circuit television, photoelectric break-beam, line and point types. Models dealing with guards include guard patrol, guard fixed post, visual and aural detection, and lighting. Penetration activities include barriers, locked doors, and

vaults. Detection provides the start signal for responding guard forces. The guard response and time of arrival depend on the force posture, procedures, and the characteristics of the facility. The model terminates the adversary action sequence with the arrival of either the attackers or the security force at the protected area. Engagement simulation is avoided by terminating the adversary action sequence prior to an engagement. Extensive geometric route analysis is implicit in route optimization.

2.7 MODEL - FIXED SITE NEUTRALIZATION MODEL (FSNM)[9]

DEVELOPER	- Vector Research Incorporated (for Sandia Laboratories)
LANGUAGE	- Unknown (probably FORTRAN)
PERSONS INCLUDED	- Security force, adversaries
PERSONNEL ATTRIBUTES	- Type, physical status, location, allegiance, credentials, situation suppression, posture, weapons, ammunition, equipment, leader, subordinates, communication nets, perceptions, current activity time requirement, activity plans, standard operating procedures, activities to which victim
PERSONNEL FUNCTIONS	- Movement, firing, observation, communication, planning, perception, sensory detection

DISCUSSION - Very little information is available on FSNM, the description presented here is based on a set of briefing charts. FSNM is basically an engagement model with very careful characterization of the involved persons. However, it is implied in the briefing paper that FSNM is a gaming model. If this is the case, the amount of actual modeling of human reactions and interactions may be very limited (i.e., depending in large part upon input from the players). Certainly a large number of human factors attributes are included in the model and much human performance and interaction is implied. For these reasons, it is considered important to obtain more information on the FSNM, and this end detailed documentation will be requested from Sandia Laboratories.

2.8 MODEL - PHYSICAL SECURITY SYSTEM PERFORMANCE ANALYSIS METHODOLOGY (SSPAM)[10]

DEVELOPER - Mission Research Corporation (for Defense Nuclear Agency)

LANGUAGE - FORTRAN IV

PERSONS INCLUDED - Adversaries, patrol guard, static point guard, entry controller, intrusion detection alarm monitor, communicator, Sgt. of guard, Site Commander, visitors, maintenance persons

PERSONNEL ATTRIBUTES - Identity, location, velocity, probability of visually detecting target, perceived probability of visually being detected by target, probability of aural detection of target, posture, penetration aids, penetration skills, dedication, experience under stress, training/organization, overt/covert intent, credentials, sound levels (e.g., talking, moving), brightness contrast, reflectivity, auditory threshold, average ratio of hours duty to rest, ratio hours duty to rest last shift, shift, average ratio motivational enrichment to duty, motivation level, average ratio hours on-job-training to duty, time of arousal level, reference time for arousal decay, training duration, training quality, level of experience, proficiency, weight

PERSONNEL FUNCTIONS -

Adversaries: Motion, search, detect, identify, select response to specified situation, penetrate barrier, tamper with sensor or sensor communications, open a lock, hide, evade

Security personnel: Motion, search, detect, identify, select response to specified situation, communicate, monitor display, control entry, verify credentials, challenge, physical search, detain, communicate

ENGAGEMENT - None

DISCUSSION - The SSPAM is still in development, thus the above information represents current status. As can be seen a number of human factors attributes have been included in SSPAM, together with a limited number of human performance models. The information upon which these models are based ranges from high quality experimental data (e.g., video display target detection and identification) to expert opinion estimates (e.g., personnel response to specified situations). SSPAM represents a first attempt to include a significant level of human factors attributes and human performance models in a physical security system evaluation model.

2.9 MODEL: EASI[11]

DEVELOPING AGENCY: Sandia Laboratories

DESCRIPTION: A simple, easy-to-use method, called Estimate of Adversary Sequence Interruption (EASI), has been developed to evaluate physical security system performance under specified conditions of threat and system operation. The method consists of a probabilistic analysis of the interactions of basic security functions, such as detection, communications, response, etc. The evaluation can be performed on a hand-held programmable calculator. The results of the analysis are expressed in terms of the probability that the physical protection system can respond in time to interrupt specific adversary action sequences. The utility of the method depends upon the user's ability to identify significant adversary action sequences and to obtain data that properly reflect conditions created by the adversary action sequence of interest.

2.10 MODEL: VISA[12,13]

DEVELOPING AGENCY: Science Applications, Inc.

DESCRIPTION: Vulnerability of Integrated Safeguards Analysis (VISA) is an evaluation concept that can be used to evaluate the effectiveness of fixed-site security systems against hostile encounters, both overt and covert. The concept is divided into three sections: preparation, analysis, and assessment. The preparation section is simply a formalization of the site data input preparation process, and the assessment section is essentially concerned with the storage of case analysis results, with procedures to assess these results at different levels of detail via an interactive display terminal. The analysis section, which includes the principal evaluation tools, consists of four analysis modules (Path, Detection, Containment, and Interruption) and requires two data bases (Detection Mechanism, and Delay Mechanism and Engagement). Included in the Containment Analysis Module is a detailed network simulation that includes aggregated delay time and engagement simulations to evaluate the probabilities of adversary success along adversary action sequence segments. VISA is a concept only, and no development has been undertaken.

2.11 MODEL: ADVERSARY ACTION MODELING[14,15]

DEVELOPING AGENCY: Lawrence Livermore Laboratory

DESCRIPTION: An assessment procedure has been developed to evaluate the effectiveness of a potential nuclear licensee's material control system. The first step in this procedure is to identify targets within the facility that contain theft-attractive special nuclear material. The second step is to determine the adversary action sequences that could allow successful diversion of special nuclear material. Simulation is used for adversary event sets where timeliness and ordering of events is important for successful diversion. The qualitative and quantitative analysis of the event sets and the simulation results allows the effectiveness of the material control system to be estimated.

2.12 MODEL: SDC TRANSPORTATION MODEL[16,17]

DEVELOPING AGENCY: Systems Development Corporation

DESCRIPTION: The SDC Transportation Model is a methodology for defining, classifying, and analyzing adversary action sequences; defining safeguards system components; assessing the vulnerability of various safeguards systems and their component parts to the potential adversary action sequences, and conceptualizing system design requirements. The method of analysis is based on a comparison of adversary actions with safeguards measures to estimate vulnerability. Because of the limited data available for assessing vulnerability, the Delphi approach is used to generate data; values are estimated in a structured exercise by a panel of experts in the safeguards and terrorist fields.

SECTION 3
ARMED FORCES INTERACTION MODELS

Because of the paucity of human performance characterization that is evident in current physical security models, the literature to be reviewed was expanded to include selected Armed Forces interaction models. The models reviewed were generally restricted to those involving company sized units, although some models that evaluate interactions among mechanized units and aircraft have been included. Some of these Armed Forces interaction models are very large gaming models (i.e., interactive models employing human "players" to represent the participating forces) and the documentation of these models frequently consists of thousands of pages. It is expected that some of these models will provide information on the approaches taken by other agencies in modeling human performance for tasks related to those performed by security personnel. In particular, the TRW-System Group, Small Infantry Action Force model (SIAF) and the General Research Corporation CARMONETTE model are know to include quite a few human factors attributes and some human performance models. These, and appropriate submodels of other applicable Armed Forces interaction models, will be reviewed in detail during the Algorithm Development Task to help identify modeling techniques for possible inclusion in the shipboard security behavioral model.

3.1 MODEL: ARMED ESCORT MODEL[18,19]

DEVELOPING AGENCY: Electronic Associates, Inc.

DESCRIPTION: The Armed Escort Model is a set of computer programs to simulate an engagement between a single ground weapon and a formation of troop-carrying helicopters (UH-1) escorted by a single armed aircraft. The model evaluates the effectiveness of differenct escort aircraft performing various maneuvers, armed with different weapon systems, and provides data for use in a comparison study. A dual-purpose digital simulation program evaluates the outcome of a single engagement in terms of expected numbers of aircraft lost, probabilities of specific damage inflicted, and similar results. The first objective was to provide a model to be used in studying the outcome of an engagement between the single ground weapon and an unescorted formation of lift aircraft that first approach the weapon position, hover for several seconds to unload or take on troops, and then pull out along prescribed flight path. The second objective was to provide a computer model to evaluate the outcome of a similar engagement including an armed escort aircraft.

3.2 MODEL: AIRCAV[20,21]

DEVELOPING AGENCY: Vector Research, Inc.

DESCRIPTION: AIRCAV is a set of two differential model programs incorporating attack helicopters and air defense weapon activities, differing principally in the detailed assumptions and logic of their ground scenarios and the format of their data bases. Both models treat a battalion-level engagement between Red and Blue forces, with Blue forces including attack helicopters in direct support and Red forces including air defense weapons. These programs were constructed as modifications of existing differential model programs treating ground combat without attack helicopter support. The scenarios were therefore constructed as modifications of basic ground combat scenarios.

3.3 MODEL: AMSWAG[22]

DEVELOPING AGENCY: Army Material Systems Analysis Agency

DESCRIPTION: The AMSAA War Game (AMSWAG) model is a time sequenced, deterministic, battalion-level, force-on-force computer model that simulates a classical attack and defense. Up to 64 defenders are deployed in fixed positions in hull defilade. The attacking force has already deployed and moves along predetermined routes of advance toward the defender. The attacking force is allowed a maximum of 12 routes of approach. The routes are administratively broken into one to three groupings of up to four routes each. These groupings are called axes, and each axis nominally contains a company-sized force. Thus, each route nominally contains a platoon. This platoon can be further split into two homogeneous sections (of two to four vehicles each) that maneuver together down the route. Normal movement techniques for these sections are either alternate bounds or successive bounds. The model conducts the battle in uniform time steps of 10 seconds each.

3.4 MODEL: CARMONETTE[23-31]

DEVELOPING AGENCY: General Research Corporation

DESCRIPTION: CARMONETTE is a critical-event-sequenced infantry combat simulation including the activities of movement, target acquisition, communications, and weapon employment. When a unit comes within line of sight of an enemy unit, it has a probability of acquiring information about the enemy as a target. The informaion it may acquire ranges from none to full knowledge of the exact location and nature of the enemy unit. If the unit gets sufficient information and has an appropriate order, it will select weapons and ammunition and take the enemy under fire. A weapon is simulated in terms of its rate of fire and its maximum range. The effects of a projectile are simulated by tables giving the probabilities that it will hit what it was aimed at as a function of the range and the size of the target, and by further tables giving the probability that it will kill the target if it is hit. Explosive projectiles are characterized in terms described on the basis of their average rates of movement under various conditions and in terms of their vulnerability to different kinds of weapons. Aircraft are characterized by their vertical and horizontal components of velocity and their vulnerability. Firing may be terminated by lack of ammunition, loss of target information, death of firing unit, known death of the target unit, or expenditure of an ordered amount of ammunition or by passage of a specified time interval.

3.5 MODEL: DYNTACS[32-38]

DEVELOPING AGENCY: Ohio State University

DESCRIPTION: DYNTACS is a small-unit, high-resolution simulation that can represent combat engagements ranging in size from a single element to a reinforced armored battalion. Attack, defense, delay, and meeting engagements can be portrayed. Armor, artillery, air defense, attack helicopters, crew-served weapons, and mounted infantry in the attack are modeled. Dismounted infantry are not modeled; the smallest resolution is the individual vehicle. Combat is represented as an adaptive process where each unit is constantly evaluating the battle situation in order to choose the tactic most appropriate for the tactical doctrine expressed by the input data.

3.6 MODEL: JOLIWACO[39,40]

DEVELOPING AGENCY: Control Data Corporation

DESCRIPTION: Joint Limited War Counterinsurgency Operations (JOLIWACO) is a computer-assisted manual war game between an insurgent force and a counter-insurgent force. An indigenous population also is assumed with the ability to provide intelligence, manpower, and supplies to either side. Depending on the scenario, any level of operations (village to national) may be modeled. Human players determine mission and policy. Lanchester-type models are used to determine outcomes of intelligence missions, engagements, and so on. Game outputs include resources consumed, casualties suffered, and mission results for the two forces and the indigenous population.

3.7 MODEL: SIAF[41-47]

DEVELOPING AGENCY: TRW Systems Group

DESCRIPTION: The Small Independent Action Force (SIAF) computer model has been developed to analyze the effectiveness of small patrols. In the model, patrols of up to 20 men can cover an area of about 25 km^2. The model simulates the detection and engagement of enemy units involving less than 20 men or positions and can accomodate a time period of up to 10 days. A combination of graph ("grid") and event-driven techniques is used for the simulation. Submodels include enemy situation, command and control, communications, human maintenance, supply maintenance, fire support, surveillance/detection, navigation, movement, terrain, and weather. Output consists of an event table providing what happened at what time. The SIAF engagement model avoids the use of Lanchester models by keeping track of the performance and vulnerability of each combatant.

3.8 MODEL: TAM[48]

DEVELOPING AGENCY: Army Concepts Analysis Agency

DESCRIPTION: The Target Acquisition Model (TAM) simulates the acquisition of targets in a target force by the sensors of an acquiring force. The model generates acquisition events that result in requests for fire missions to be delivered by an artillery firing force. The target force is represented by a static target array which is modeled at the small-unit level of resolution. The acquiring force is modeled at the individual-sensor level of resolution. The model addresses input target arrays for a six hour time period and produces a history of acquisition events.

SECTION 4
SMALL GROUP ENGAGEMENT MODELS

In addition to the small group encounter models described in this section, it should also be noted that engagement models are included in many of the Armed Forces interaction models described in Section 3 and in some of the security system evaluation models described in Section 2. In reading the engagement model descriptions, it will be observed that many of the models reviewed are based on Lanchester Technology. Lanchester models are based on simultaneous differential equations of the form (guards ambush adversaries)

$$\frac{dN_A}{dt} = \gamma_1 N_A N_G / \beta \qquad \text{(linear law)}$$

$$\frac{dN_G}{dt} = \gamma_2 N_A \qquad \text{(square law)}$$

where

dN_A/dt = attrition rate of adversaries

dN_G/dt = attrition rate of guards

γ_1 = adversary attrition coefficient, dependent on guard rate of fire

N_A/β = adversary exposure coefficient

γ_2 = guard attrition coefficient, dependent on adversary fire rate and accuracy

A larger number than two simultaneous equations may be used, and the equations may contain more coefficients than shown, with the intent of including more characteristics of the opposing forces. Additionally, the coefficients may be time dependent with the intent of reflecting changes in force posture during the engagement. The definition of the derivation dN/dt is given by

$$\frac{dN}{dt} = \lim_{t_1 \to t_2} \left[\frac{N(t_2) - N(t_1)}{t_2 - t_1} \right] .$$

Thus, there is no theoretical inconsistency is using a differential equation or, more appropriately, a finite difference equation, approach to modeling small group engagements. The difficulties lie in its inflexibility and the availability of more appropriate techniques. The differential equation approach does not allow for situation assessment, manuevering to gain positional advantage, changes in tactics, etc., that may be important factors in determining the outcome of a small group engagement. In the case of large group (i.e., battalion size) encounters, these factors may be of less significance and certainly change more slowly. Further, in large group encounters, it is not possible (and probably not desirable) to keep track of all the combatants and maintain a record of each participant's performance and vulnerability. However, this can be done in the case of small group engagements and is considered by many to be an appropriate way to model such engagements. This approach has the advantage of allowing frequent situation assessment, alteration of tactics as the situation changes, movement to improve positional advantage, the effects of new arrivals, partitioning of the involved forces, etc. For these reasons, it is considered that an appropriate approach for modeling small group engagements should be one that maintains a running account of the performance and vulnerability of the participants. Some examples of this type engagement model are the approaches taken by SABRES,[49] described in SPPAM[10] and employed by SIAF.[42]

4.1 MODEL: SABRES

DEVELOPING AGENCY: Sandia Laboratories[49,50,51]

DESCRIPTION: SABRES is a time-stepped Monte Carlo simulation developed to evaluate the outcomes of engagements between attackers and defenders after a transport vehicle has been stopped. At every time step, detection, posture, firing allocation, casualty assessment, suppression, and disengagement are considered for each participant, and the results are catalogued before moving to the next time step. The battle terminates when one side disengages. The program outputs for a series of replications of an ambush are the expected survivors on each side, the fraction of time each side is totally successful, and the expected battle time.

4.2 MODEL: SCHAFFER'S AMBUSH MODEL[52]

DEVELOPING AGENCY: Naval Postgraduate School

DESCRIPTION: The Schaffer Ambush model is a mixed Lanchester linear/square-law attrition model that is representative of the many Lanchester-type simulations that could be used to evaluate the outcomes of engagements involving ambushes. The model assumes an ambusher force in concealed positions and initiates a surprise attack when the ambushee force arrives in a specified "killing zone." The ambushers' initial fire is aimed (Lanchester square law) while the ambushees initially react wtih area fire (Lanchester linear law). As the ambushees locate cover and begin to detect ambusher fire locations, they gradually switch from area to aimed fire. The ambushers maintain aimed fire throughout the engagement but with decreasing effectiveness as the engagement progresses. Ambushee desertions and ambusher withdrawals are considered (dedication/training) in the simulation and supporting weapons for the ambusher can also be included. For the initial surprise attack, the use of claymore mines is also an option.

4.3 MODEL: SOURCE[51,52,53]

DEVELOPING AGENCY: Sandia Laboratories

DESCRIPTION: The SOURCE model is used to study the impact of convoy configuration and tactics upon personnel survival and emergency signal generation during an initial armed attack. SOURCE is a flexible, time-stepped Monte Carlo model that provides for extensive variations in convoy configuration (number of vehicles, distributions, vulnerabilities, velocity, and communications) and in adversary characterization (number of units, deployment, and weapon capabilities). The convoy is described by the number of vehicles, vulnerable areas, observation conditions, and communications capabilities. Convoys consisting of a number of different types of vehicles can be studied. Emergency messages can be initiated, either by a vehicle under attack or by a vehicle that has observed an attack on another vehicle. The conditions under which an attack is observed can be varied, and the capability of sending a message depends on the condition of the convoy crew and their equipment. SOURCE calculates the damage to personnel and equipment and includes the cumulative effects of multiple hits on a vehicle.

4.4 MODEL: TSEM[54,55,56]

DEVELOPING AGENCY: The BDM Corporation

DESCRIPTION: TSEM (Transportation Safeguards Effectiveness Model) is designed to simulate a two-sided engagement between a group of adversaries and a road convoy. TSEM is a discrete, stochastic, event-driven simulation that individually models persons (with their associated weapons) and vehicles. The players in TSEM (i.e., persons and vehicles) can be directed by a script that includes actions (movement, firing, and dismounting) and contingency situations (player or vehicle at a location, players dead, attack started). The battles take place on a two-dimensional surface with topography and vegetation superimposed. Line-of-sight interruptions due to vehicles and terrain and vegetation features are calculated and taken into account in firing allocation. The battle progresses until all people on one side are killed, a preset time limit is reached, or prime vehicle penetration is successfully completed. A movie can be produced that shows the course of the battle, including player movements and shots fired.

4.5 MODEL: ANALYTIC ENGAGEMENT MODEL[57]

DEVELOPING AGENCY: Sandia Laboratories

DESCRIPTION: The Analytic Engagement Model is a discrete-state, continuous-time stochastic process. The state of the battle is described in terms of the number of guards and adversaries actively engaged in battle, together with the number of arrivals to each of the opposing forces. The solution procedure is analytical in nature and involves solving sets of linear equations. For small battles, consisting of one or two combatants on each side, symbolic solutions can be found. The procedure can be used to compute analytic numerical solutions for larger battles with a total of less than ten combatants on both sides.

4.6 MODEL: BONDER/IUA[58]

DEVELOPING AGENCY: Army Material Systems Analysis Agency

DESCRIPTION: The Bonder/IUA model is an adaptation of the general Bonder methodology to the Individual Unit Action (IUA) model scenarios. The Bonder model is a generalized differential equation model of ground combat. It is an extension of the Lanchester analytic formulations. In contrast to the classical Lanchester approach, which bases attrition rates on historical data, this model estimates attrition rates based on measurable weapon system parameters. It also allows a force to use more than one weapon type. Weapons of a given type in the same general location are aggregated into a single group. Different types of weapons and weapons of the same type in different locations are treated as distinct groups.

4.7 MODEL: BREAKPOINTS IN LAND COMBAT[59]

DEVELOPING AGENCY: Naval Postgraduate School

DESCRIPTION: This concept considers battle termination (a unit reaching its so-called "breakpoint') in ground combat as a rational decision process. A commander's decision to break contact with an enemy force and withdraw from the battlefield is analyzed for company-size infantry units. Two approaches for modeling a commander's decision process to terminate an engagement are presented. The first approach is based on extrapolation of observations on past battle history into the future with no assumption about combat dynamics. The second is based on the assumption of known Lanchester-type combat dynamics (possibly with unknown parameters to be estimated) and uses Kalman filtering.

4.8 MODEL: COUNTERMEASURES ENGAGEMENT ANALYSIS[60]

DEVELOPING AGENCY: Air Force Institute of Technology

DESCRIPTION: This analysis involved the construction of a computer model to study a one-on-one engagement. It is built so that paramenters in the radio frequency or optical regime can be used. The aircraft flies over the threat, is not allowed to maneuver, and the atmosphere has been ignored.

Fly-By-1 introduces the techniques employed by the GASP IV simulation language. The aircraft is detected when it comes within range. In Fly-By-2, a more probabilistic determination of detection is used, and the radar scans for the aircraft. Fly-By-3 makes 20 runs of the Fly-By-2 program and collects statistics on the range of detection. Fly-By-4 incorporates a track-and-fire role into the threat.

4.9 MODEL: DAYLIGHT ASSAULT MODEL[61]

DEVELOPING AGENCY: Naval Postgraduate School

DESCRIPTION: With Lanchester's Square Law providing a point of departure, a model of small-unit combat was developed in which major parameters of an encounter known to be time- or range-dependent were so treated, thus incorporating realism of dynamic combat. The single uncontrolled variable of the model is force size. Force sizes are specified at the start of each computer program and every one-tenth of a minute of the battle. The remaining variables are controlled in that they were either assumed, calculated from other data, or directly input as values from other research. Success in battle is considered dependent upon infliction of casualties on the opposing force and on the range between the forces at the termination of the engagement.

4.10 MODEL: FIREFIGHT[62]

DEVELOPING AGENCY: SRI International

DESCRIPTION: FIREFIGHT is a computer model developed to evaluate the effectiveness of alternative small arms, using the criterion of tactical mission success probability. It can be used to evaluate rifles, machineguns, grenade launchers, and grenades. Mortar, artillery, and other supporting fires are not modeled. This small-unit engagement model can also be used to study tactics or nonweapon equipment options.

4.11 MODEL: GCC FIREFIGHT[63]

DEVELOPING AGENCY: Naval Weapons Laboratory

DESCRIPTION: The Firefight Submodel of the Ground Combat Confrontation (GCC) is a military operations analysis tool designed to assess the results of close combat between opposing forces of mixed infantry and mechanized units. The forces are considered to be composed of "fire units" (such as a USMC fire team or a single tank) which are elements of the forces that have their target acquisition, fire, and movement internally coordinated. Detailed round-by-round assessments are given to the fire of individual crew-served tank and antitank weapons belonging to a fire unit. The lethal and suppressive effects of individual projectiles are considered in terms of the activity and presentation of the target fire unit.

4.12 MODEL: ICM[64]

DEVELOPING AGENCY: Army Concepts Analysis Agency

DESCRIPTION: The Infantry Combat Model (ICM) is a two-sided ground combat model that simulates small infantry unit engagements of close combat over successive finite time intervals. The units can contain varying numbers of personnel with a variety of direct-fire weapons. Each unit can be augmented by reserve forces and can be supported by indirect fire of varying types. Each engagement is evaluated on the basis of assessing personnel casualties and ammunition expenditures in successive time intervals. The results are accumulated until the exchange terminates based on predetermined conditions. Each engagement is replicated and the results are averaged. The model output consists of average personnel casualties for both sides, direct- and indirect-fire weapon ammunition expenditures, termination distances between opposing forces, direct-fire weapon attrition, and average engagement time.

4.13 MODEL: INTERDICTION MODEL[65]

DEVELOPING AGENCY: Rand Corporation

DESCRIPTION: The Interdiction Model is an algorithm for determining where to place forces in order to maximize the probability of preventing an opposing force from proceeding from one particular node in a network to another.

The usual gaming assumptions are invoked in this model—namely, that the strategy for placing forces is known to the opponent and that he will choose a path through the network that, based on this knowledge, maximizes his probability of successful traverse. As given quantities, the model requires a list of the arcs and nodes of the network, the number of forces available to stop the opposing force, and the probabilities for stopping the opposition at the arcs and nodes as functions of the number of forces placed there. From these data, the model calculates the probabilities of success for placing the force at the arcs and nodes when one force is available and the expected numbers of forces to place at the arcs and nodes when multiple forces are available.

4.14 MODEL: MARKOV ENGAGEMENT MODEL[66]

DEVELOPING AGENCY: Vector Research, Inc.

DESCRIPTION: The Markov Engagement Model is a conceptual formulization of a Markov or Semi-Markov model to evaluate the outcome between a set of attackers and a guard force. The range between opposing participants is maintained constant. The model allows for the possibility of arriving forces joining one side or both. The model does not allow for range closure, changes in force posture, exhaustion of ammunition supplies, and so on. However, modifications of the process are suggested to overcome some of the restrictions.

4.15 MODEL: MATH MODEL OF INFANTRY COMBAT[67]

DEVELOPING AGENCY: Naval Postgraduate School

DESCRIPTION: This is a deterministic combat model that takes into account the phenomenon of fire suppression. This model, based on Lanchester's theories of combat, can be used to investigate the offensive tactics and defensive fire distribution of a small-scale infantry action. Specifically, the type of action covered is an attack against a defended position. The missions of the attacking and defending units are, respectively, to gain or maintain control of the defended position while holding their own casualties to a minimum. The offensive force has two tactics it can employ—advance its entire force against the enemy or advance only a portion of its force while using the remainder to lay down covering fire. The defense then has to decide how to divide its fire to engage the attacking elements.

4.16 MODEL: PENETRATION ATTRITION MODEL[68]

DEVELOPING AGENCY: Institute for Defense Analyses

DESCRIPTION: The Penetration Attrition Model is a probabilistic model designed to evaluate combat attrition between attackers (infiltrators) and defenders attempting to defend a passive target. Infiltrators attempt to reach a target successively, one after another. An infiltrator is detected by each defender present with a constant probability independent of any other defender and of past history. When a detection occurs, exactly one defender is assigned to engage the infiltrator. One-on-one engagements are evaluated by assigning probabilities, independent of past history, to the possible outcomes. Probability distributions are computed for infiltrators destroyed, infiltrators reaching target, and defenders destroyed, all conditioned on a specified number of attempted penetrations.

SECTION 5

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